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Extending RTM Imaging With a Focus on Head Waves

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Conventional industry seismic imaging predominantly focuses on pre-critical reflections, muting post-critical arrivals in the process. This standard approach neglects a lot of information present in the recorded wave field. This negligence has been partially remedied with the inclusion of head waves in more advanced imaging techniques, like Full Waveform Inversion (FWI). We would like to see post-critical information leave the realm of labour-intensive travel-time picking and tomographic inversion towards full migration to improve subsurface imaging and parameter estimation.

We present a novel seismic imaging approach aimed at exploiting post-critical information, using the constant travel path for head-waves between shots. To this end, we propose to generalize conventional Reverse Time Migration (RTM) to scenarios where the sources for the forward and backward propagated wave-fields are not coinciding. RTM functions on the principle that backward propagated receiver data, due to a source at some locations, must overlap with the forward propagated source wave field, from the same source location, at subsurface scatterers. Where the wave-fields overlap in the subsurface there is a peak at the zero-lag cross-correlation, and this peak is used for the imaging.

For the inclusion of head waves, we propose to relax the condition of coincident sources. This means that wave-fields, from non-coincident-sources, will not overlap properly in the subsurface anymore. We can make the wave-fields overlap in the subsurface again, by time shifting either the forward or backward propagated wave-fields until the wave-fields overlap. This is the same as imaging at non-zero cross-correlation lags, where the lag is the travel time difference between the two wave-fields for a given event. This allows us to steer which arrivals we would like to use for imaging. In the simplest case we could use Eikonal travel-times to generate our migration image, or we exclusively image the subsurface with the head wave from the nth-layer.

To illustrate the method we apply it to a layered Earth model with five layers and compare it to conventional RTM. We will show that conventional RTM highlights interfaces, while our head-wave based images highlight layers, producing fundamentally different images. We also demonstrate that our proposed imaging scheme is more sensitive to the velocity model than conventional RTM, which is important for improved velocity model building in the future.